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A Program for Control of Black Shank Based on a New Conception of the Life History of the Fungus

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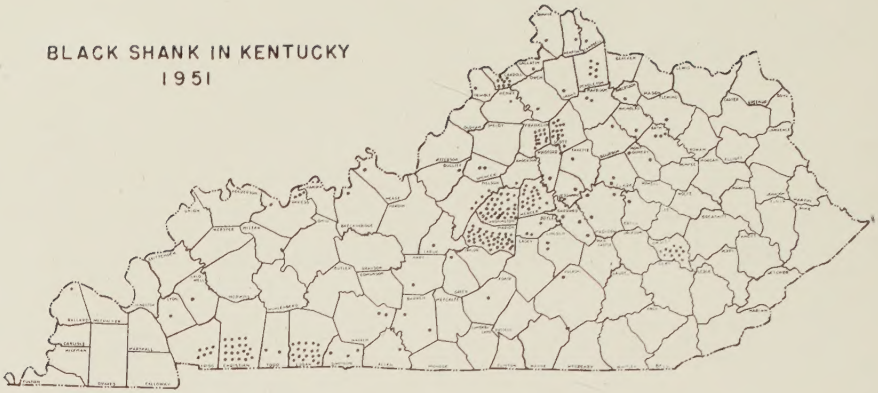

Location and general concentration of black shank in Kentucky in 1951, based on specimens sent to the Department of Agronomy and on reports by county agents. In counties reporting the disease the number of farms having black shank ranged from one or a few to more than 600. Concentration was highest in Marion, Washington, Mercer, Franklin, Scott, Carroll, Christian, Logan, and Owsley counties.

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FOREWORD

This bulletin is prepared for the guidance of people in areas where black shank is prevalent and where every means must be taken immediately to reduce losses from the disease.

The plan outlined has not been tried in other states where black shank has been destructive for years, but the essential features of it have been tested in Kentucky successfully. The program is based on a different conception of the life history of the fungus than that generally accepted, and evidence, so far as it exists, will be presented to support the new interpretation. There is no question that further research will be necessary to firmly establish some points in the life history, but this research will be carried out.

While in other areas resistant varieties have been developed, they have been completely successful only where enough land is available for a 2-year rotation. While there are fairly good moderately resistant varieties of burley, it seems probable that the program of control presented here will be better served by using our present susceptible varieties than by using varieties with the degree of resistance found in the presently known resistant varieties. The reasons for this belief will be presented.

The recommendations for tobacco growers who have only one piece of ground available may seem drastic; but if tobacco is grown in these fields year after year, even with the present resistant varieties, the losses will be great. The grower will be much better off to drop out of tobacco production completely for one year, as there are now excellent reasons for believing that the fungus will be reduced to a point where, with proper care, a susceptible variety may be grown continuously thereafter.

While the situation is extremely serious in large areas of the state, it is by no means hopeless, and a concerted effort the coming season should be made by every grower in infested areas to avoid damage from the disease and do what he can to free his farm as rapidly as possible from the black shank fungus. Success the coming season will not mean that the danger is over. A warning should be given at this time that plans for several years ahead should be made and followed.

Fig. 1.— A root system of a tobacco plant killed by the black shank fungus. The spores of the fungus are carried over winter in all parts of the root system, the smallest bits of which are able to start the disease the next year. This illustrates why plants should be removed as soon as they show the first signs of the disease, and the soil drenched with Nabam.

A Program for Control of Black Shank Based on a New Conception of the Life History of the Fungus

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Black shank has been present in Kentucky since before 1935. It has spread gradually until at present it has been reported in about 60 counties. In some parts of Marion, Mercer, and Washington counties it has spread to nearly all farms and is causing serious losses. In other counties, as Todd, Nicholas, and Owen, it was eradicated immediately following its first appearance several years ago by putting the fields in which it occurred in grass, and these counties remained free for several years.

The first spread is usually along creeks and rivers, where tobacco is grown on overflow land, followed by farm-to-farm spread as a result of trading labor and borrowing and lending machinery. The fungus that causes black shank is readily carried in water, and in dirt that clings to machinery, automobiles, shoes, and to the feet of animals. If the dirt is dropped off in a tobacco planting, black shank may follow; or if it is dropped off in a field that is to go into tobacco soon the disease may then develop.

It is the purpose of this bulletin to describe the disease, its cause, methods by which it can be prevented from spreading, and methods by which it can be eradicated once it is brought onto a farm. The approach to the problem is new, but there seems to be sufficient evidence to indicate that this approach to control of the disease is sound and workable. It is realized that the program is not simple and that it will take a great deal of educational work, but there is no alternative if the industry is to prosper until good highly resistant varieties become available.

The Disease

Black shank causes tobacco plants to look as though they had been drowned; and many growers in the wet season of 1950 mistook a few plants that were dying from black shank for drowned plants, only to put the field back in tobacco in 1951 with a total loss. The fungus that causes black shank lives through the winter in the soil and attacks tobacco any time during the summer.

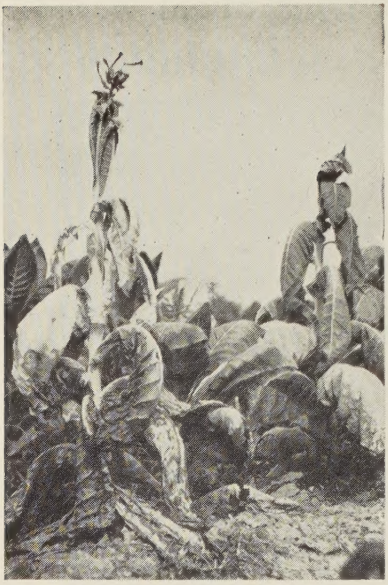

Fig. 2.— Black shank; the leaves have wilted and yellowed and are dying.

The first signs of the disease are a slight yellowing and wilting followed by the leaves turning bright yellow and hanging down the stalk. At this stage the roots usually will be found to be dead and a black rot may have spread up the stalk for several inches. If the stalk is split the rot will usually be found to have entered the pith, which it darkens and causes to separate into disks.

Not very much is known about where or how infection first occurs on a plant. Greenhouse tests, in which the cut ends of roots are placed on a mat of leaves decaying from black shank, have not resulted in any apparent injury to susceptible plants, suggesting that root infection, if it occurs, may not result in rapid death of the plant. Sometimes infection takes place on a leaf and the fungus spreads back into the stalk, causing death of the bark as well as the pith. In this case the plant may yellow and wilt while the roots are still healthy. It is possible that infection occurs in the field only through the underground stem or through the leaves. The fungus is present in some form in dead roots and in the base of the plant, where it may overwinter. It also overwinters in soil from which the visible pieces of roots have been removed.

Quick Identification of the Disease

It is not always a simple matter, particularly in small, recently set plants where pith is not present for examination, to identify the disease

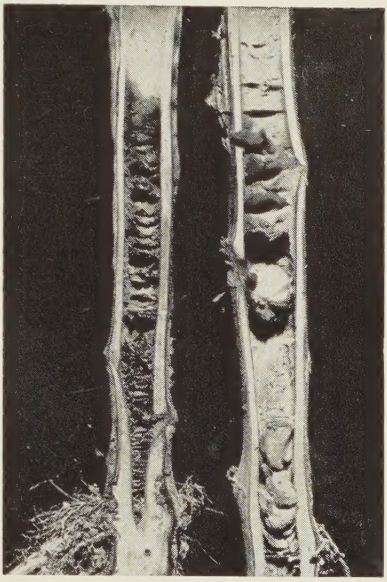

Fig. 3.— The shank of the plant is blackened from the roots upward, and the roots are decayed.

Fig. 4.—The insides of two stalks split lengthwise showing blackening and disking of the pith. The stalk on the right had evidently been infected through two leaves. There is an area of normal pith between the infected areas.

accurately. The following method has been used successfully, however, for determining whether or not bits of root or stalk or particles of soil carry the black shank fungus. About an inch or two of rain water or cistern water is placed in a common glass tumbler or other glass container, a few bits of the blackened tissue of the plant or soil to be tested are added, and the butt end of a tobacco leaf is placed in the water. If the leaf is then kept at a temperature around 75° F for 2 or 3 days it will begin to decay if the disease is black shank. There is a possibility that black shank and a pythium soft rot, that decays the underground stems of newly set plants, might be confused by this test; but black shank ordinarily does not appear at this early season.

If a microscope is available, the sporangia or lemon-shaped spores may be found on the leaf if black shank is present, and in about 15 minutes the rapidly swimming swarm spores will appear.

Losses From Black Shank

It is not necessary to mention the losses that can result from black shank to those in black shank areas where crop after crop is injured

or completely destroyed, but for those who have not witnessed an outbreak of the disease examples of losses may be a warning to be on the alert so that at the first appearance of the disease measures can be taken against it.

On one farm a small area in an 18-acre field of burley was partly overflowed in 1950 and some plants died from black shank. That fall the field was sown to a small grain and vetch, and probably in the preparation of the land for sowing, the black shank fungus was well distributed over the remainder of the field. The next year the same field was planted to burley, and by August 1, 15 acres were so severely injured that this part of the field was disked. In 2 more weeks the other 3 acres were a total loss. If the tobacco had been put on a fresh piece of ground there might have been loss of a few plants as a result of using dirty machinery, but certainly not the whole field.

Another farmer had a field of about 6 acres of burley in which he said he had seen six or seven black shank plants in 1950. The field was planted with a cover crop in the fall and set with tobacco in 1951. By the first of August 4½ acres were a total loss and had been abandoned, and plants in the remaining area continued to die until harvest time. The same man planted a clean field across the road with tobacco, used the same equipment, and carried black shank into it, but lost only a few plants. This is typical of the losses that occur the first year a field becomes contaminated.

Many other cases could be mentioned of partial to complete loss where growers had used an infested field a second or third year for tobacco, but it is rare that the loss is more than a few plants the first year the disease appears in a field. Some growers may not agree with this statement, but the usual story is that the grower who has had serious damage to his crop had noticed a few "drowned" plants the year before. A field in which any black shank plants are found is not safe to use for tobacco the next year unless special precautions are taken.

Cause of Black Shank

Black shank is caused by a mold or fungus (*Phytophthora parasitica* var. *nicotianae*) that can be readily seen in small bits of the discolored decaying pith if it is examined under the low power of the microscope, or sometimes it may be seen as a moldy growth between the disks of the pith.

There are two other fungi that sometimes cause a disease very similar to black shank. These are *Rhizoctonia solani* and *Sclerotium bataticola*, the causes of the so-called sore shin disease. These fungi

can usually be distinguished from the black shank fungus because each of them develops hyphae or fungus threads that are septate or have cross walls, while the black shank fungus is nonseptate and forms a continuous branched tube with no cross walls except in old cells. Furthermore, *Sclerotium bataticola* produces pin-point sized black bodies or sclerotia in the decayed pith. This fungus usually affects plants at a temperature above 90° F. *Rhizoctonia solani* is seen in the pith as brownish coarse threads in contrast to the white threads of the black shank fungus. It does not cause as much yellowing of the leaves as black shank and it may cause depressed dead areas in the bark above the blackened shank.

Many specimens of lightning injury have been received at the Experiment Station in the belief that they might be black shank. The dead midveins, the collapsed leathery stalk in some lightning-injured plants, the lack of yellowing in the leaves, and the healthy root system should distinguish lightning injury from black shank.

The black shank fungus produces heavy walled chlamydospores or resting spores in the dead tissue, and it probably is these spores that carry the fungus over from one season to the next. It is also probable that these spores are carried by water in bits of dead tobacco plants, and deposited on overflow land. Another type of reproductive body known as a sporangium is borne sometimes in large numbers on the aerial hyphae that develop on the surface of leaves or the stalk in continued wet weather. In the greenhouse the sporangia develop in less than 48 hours following inoculation of a leaf. It is possible that these bodies are sometimes carried in the air and may be a means of spreading the disease for some distance, although there is but little evidence of spread by this means. Each sporangium discharges about thirty swarm spores if placed in water at a temperature of about 58° F or above, so there may be an enormous and sudden multiplication of the fungus during a short rainy period, in a field with dying plants left in it. It is thought that the swarm spores cause most of the infections during the summer, particularly along waterways, as they are produced only in water. They cause infection to uninjured leaves, through either the lower or the upper surface.

Methods of Spread

Black shank is readily spread by water during rainy periods. Creeks that overflow a part of a tobacco field during the summer may result in a few affected plants, or water flowing from an infested field to another tobacco field may start the disease. Water used for watering plant beds or for setting, if it comes from a creek or river that

receives drainage water from black shank fields, may be contaminated and cause black shank in the field where it is used.

Small masses of soil from around diseased plants, if they stick to machinery, shoes, or animals' feet, may be carried down the row or may be carried from one field to another. The disease, if carried on tools, usually is found where the tools are first used, as near a gate or corner of the field. Neighborhoods where the disease spreads most rapidly are those where labor and machinery are commonly traded from farm to farm.

Also, black shank is spread from one area to another by bulldozers and other heavy dirt-moving equipment which may be hired for some special work on the farm. A field that has been bulldozed should not be planted to tobacco for at least a year after the bulldozing is done. Farmers who move from a black-shank farm, in order to get away from the disease, to an area where the disease is not present, sometimes carry it in masses of dirt on machinery. Automobiles undoubtedly pick up dirt from roads that have been flooded with water draining from a black shank field. It is probable that tenants on farms where black shank is present will want to move to clean farms, although there is no reason why they should. There is great danger that they will carry black shank with them on machinery and tools, and farmers contracting with a new tenant should see to it that everything brought on his farm is freed from dirt. If this is not done before arrival, the tools and machinery should be cleaned on a grass plot which will not endanger the next tobacco crop. Farmers from a black shank area visiting a free area could carry the black shank fungus on tires, fenders, and shoes, and contaminate the clean farm. Road maintenance machinery undoubtedly carries contaminated soil for long distances and deposits it where it could be washed into a tobacco field below road level. Several cases have been seen where only a few tobacco plants next to a road ditch were affected. Evidently the ditch water had become contaminated and, when it overflowed into the tobacco field, caused the disease.

Instances have been reported where a hunter, during the winter, walked across a black shank field and then across a field that was to be put in tobacco the following summer, and the disease was reported to have developed here and there across the field where he had walked.

There are many instances of farmers carrying the disease from overflow land to high land on their feet while setting a crop by hand. One instance is known where a farmer loaned a fertilizer distributor to another farmer 8 miles away who had black shank on his farm.

The machine was returned and used in the preparation of the owner's tobacco field and black shank developed that summer.

The disease is primarily one of small farms where tobacco land is limited and farmers trade labor and tools. Large landowners with sufficient land, who have their own tools and help, have much less to fear from the disease than farmers with small farms who borrow and lend machinery and trade labor.

Persistence of the Fungus in the Soil

One of the most useful pieces of information for the farmer who is troubled with black shank would be a knowledge of how long the fungus stays in the soil once it has become contaminated. According to one authority the fungus does not live in the soil at all, while another claims that it persists for 6 years or more. The basis for the latter statement is that the disease appeared again when tobacco was grown in a field that had not been in tobacco for 6 years. Actually, observations of this kind have little bearing on the question if they are made in concentrated tobacco areas where the cropland is nearly all plowed each season and machinery is used promiscuously on clean and infested soil, because recontamination of fields is to be expected under these conditions.

It is a common observation that the amount of infestation in the soil following an infested tobacco crop drops off rapidly when the land is used for other purposes. For example, in Florida the disease is completely controlled by growing resistant varieties in a 2-year rotation; but where equally resistant varieties of other types are grown year after year on the same ground, losses are sometimes great. This probably means that in Florida 1 year out of tobacco greatly reduces or may actually eliminate the fungus, but the chance for recontamination is great. In Georgia it is reliably reported that two fields were damaged by black shank one season, left out of tobacco the next, but planted to tobacco the third season with no injury from black shank. In Tennessee it was reported that a careful grower removed every plant that developed black shank, spot sterilized with formaldehyde, and the next year had no black shank in the field. This observation suggests that the fungus did not carry over a 2-year period. Another field has been under observation for 4 years. Black shank developed in two plants the first year. These were removed and the spots treated that fall with methyl bromide before disking and sowing to a cover crop. The next year two more plants became affected nearby; these were removed and the area treated in the fall. The third year two more plants developed black shank; the plants were removed and

the spots treated with methyl bromide. The fourth year two more plants developed black shank; they were removed and the spots treated immediately with Nabam. The loss each year was .03 percent. This shows that with care in plant removal and spot sterilization, spread of the disease during that season can be prevented and carry-over can be reduced to very little. Losses in this field were reduced to a point where commercial production on the same ground was feasible year after year.

Experimental Evidence on Disappearance of the Fungus

There is some experimental evidence that supports the theory of quick disappearance of the fungus from the soil the summer after a diseased crop. It should be realized, in considering this evidence, that staling products in the plant tissues might prevent chlamydospore germination during wet periods in the fall, and low temperature prevents germination during the winter. Sporangia produce swarm spores at a temperature above 58° F, and so it is not likely that chlamydospores will germinate until sometime in June of the year following an infected crop.

Test 1

On the theory that wetting the soil when the temperature is above 60° F will cause resting spores to germinate and, as a result, gradually rid the soil of the fungus, an attempt was made to eradicate the fungus in a ground bench in a greenhouse where the fungus had killed a row of plants being raised for seed the winter before. In July a dam was built around the infested area and the area was flooded several times during the next 3 weeks. After that a solid stand of volunteer seedling tobacco plants developed. These were watered and kept growing nearly 3 months. There was no evidence of black shank in the plants, suggesting that the fungus had been eradicated by repeated flooding of the soil.

Test 2

Soil was collected in a black-shank field, taking it only from places where dead plants were standing. Two gallons of this soil was sieved and put in a 2-gallon crock. The soil was then thoroughly wet with distilled water until the water stood on the surface. After a short time the soil was spread on clean paper and allowed to dry. This process of wetting and drying was repeated, making tests for the presence of the black shank fungus each time. The test consisted of placing about ½ inch of either the wet or dry soil in a glass tumbler, add-

ing distilled water until the soil was covered about ¾ inch. Then a small leaf of tobacco and a leaf of *Nicotiana longiflora* (immune to black shank) were placed in the tumbler, with the cut end resting on the soil. In 2 or 3 days the tobacco leaf usually was decaying if the fungus was present, while the *N. longiflora* leaf was unaffected. The results of this test were as follows (+ = decay of tobacco leaf; *N. longiflora* leaves were unaffected; — = no decay of tobacco leaf):

Nov. 25, original dry soil	Nov. 27,	+
25, original soil wet (1)	27,	+
27, soil half dry	30,	+
28, soil fairly dry	Dec. 2,	+
28, soil rewet (2);		
Dec. 1, soil dry	4,	+
1, soil rewet (3);		
4, soil partially dried	6,	+
6, soil dried 2 days longer	14,	— in 9 days
6, soil rewet (4);		
14, soil dried since Dec. 6..	17,	+
15, soil dried since Dec. 6..	20,	—
16, 17, 18, 19, 20, 21 as above		— — — — — —
26, 10 samples of soil as above		+ — — — — — — — — —
31, 10 samples of soil as above		— — — — — — — — — —
18, to 31, 9 samples of original field soil		+ + + + + + + + +

These results, while not conclusive, suggest that after four thorough wettings and dryings, covering a period of 11 days, the fungus had nearly completely disappeared from the 2-gallon sample of heavily infested soil.

Test 3

Roots and a crown of a tobacco plant, killed by black shank, were removed from the field soil such as was used in test 2. The stub and the dead roots were washed in distilled water and placed in tumblers containing distilled water. The field soil was added to a third, and it was wet with distilled water. Then a leaf of tobacco and one of *N. longiflora* were placed in each tumbler. The results were as follows (+ = tobacco leaf decaying; — = tobacco leaf unaffected):

Nov. 22, soil .....Nov. 24, +
22, roots ..... 24, +
22, stub ..... 24, +
24, same soil ..... 29, +
24, same roots ..... 28, +
24, same stub ..... 27, +
29, same soil .....Dec. 1, +
28, same roots .....Nov. 30, +
27, same stub .....Nov. 30, +
Dec. 4, same soil air dried .....Dec. 7, +
4, same roots air dried ..... 13, —
4, same stub air dried ..... 13, —
13, same soil dried again ..... 16, —

In this test, roots and a stub wet for several days and then dried no longer initiated rot in leaves. Soil wet for several days, dried, wet, and dried again no longer caused decay.

Test 4

Tobacco plants in 2-inch pots were inoculated on the leaves with swarm spores of black shank and placed in a damp chamber where the plants soon died. The plants were cut off at the ground line, the dirt washed from the roots with distilled water, and the roots placed in a tumbler about one-fourth full of distilled water, and a tobacco leaf added. The results were as follows (+ = tobacco leaf decaying; — = tobacco leaf unaffected):

Nov. 27, dead washed roots (1) .....Nov. 29, +
29, same washed roots, fresh water .....Dec. 1, +
Dec. 4, same washed roots, dried ..... 9, —
Nov. 28, dead washed roots (2) .....Nov. 30, +
30, same roots rewashed .....Dec. 2, +
Dec. 4, same roots dried ..... 9, —

In this test the freshly washed dead roots caused decay of tobacco leaves, but after drying failed to cause rot.

While these tests are by no means conclusive, they suggest that the spores in the roots can be made to germinate by repeated wettings, thus causing the fungus to disappear. Just how rapidly this will occur under field conditions will probably depend upon whether spores buried deep in the soil will find conditions suitable for germination when the soil is thoroughly wet.

In Kentucky, several instances are known where tobacco failed completely in 1947, the fields were in grass 3 years, and again set with tobacco in 1951 with no loss from black shank. These observations, together with the Georgia and Tennessee observations and the greenhouse and laboratory tests, suggest that where no opportunity is given for recontamination of the soil the fungus will disappear rapidly, the rate probably depending on the amount of rainfall during the summer.

So far as is known, the only plant commonly attacked by the fungus, under field conditions, is tobacco; therefore, in the absence of tobacco the fungus has little opportunity to multiply. In this species of fungus the overwintering type of spore forms one or more germ tubes followed by the production of a sporangium or another chlamydospore. The sporangia then produce swarm spores. The swarm spores are delicate bodies and probably perish quickly if they do not come in contact with a tobacco plant. Repeated good conditions for spore germination during the summer could only result in gradual depletion of the fungus in the soil.

There is, then, no conclusive evidence that the fungus can or does persist in the soil for several years as has been claimed. We know that in some instances it has not persisted for 3 years, and it is probable that as accurate studies are made, with all chances of recontamination eliminated, it will be found that the time required for complete eradication of the fungus from the soil is much less than has generally been thought, and possibly less than a year.

The Kentucky Program for Control of Black Shank

In the states where black shank has been destructive for many years, no concerted efforts have been made either to prevent the spread of the disease or to eradicate it when it first appeared on a new farm or in a new area. Reliance was placed entirely on the development of resistant varieties. While these varieties have a fair degree of resistance, they do not prevent the fungus from multiplying and keeping the soil contaminated year after year. In dry seasons the resistant varieties may be severely injured by black shank, provided there has been sufficient wet weather to cause infection; whereas in seasons of sufficient rainfall there may be little injury.

In Kentucky we do not have satisfactory varieties of burley or other types that are resistant to the disease. It is true that some fairly satisfactory resistant burley varieties have been developed by the Virginia Agricultural Experiment Station, but in heavily infested soil,

during the dry summer of 1951, these varieties were more severely diseased than susceptible varieties in the same fields during the wet season of 1950. Varieties of this degree of resistance will probably be successful only if used in a 2-year rotation. At the present time it is difficult to see how this degree of resistance can be very helpful in the control programs here outlined, and it may actually be a hindrance in attempting to free soil of the fungus.

Until we have satisfactory varieties of the various Kentucky types that are virtually immune to black shank (at present the prospects are good) it will be necessary for Kentucky farmers, in black shank areas, to change farming practices that have resulted in the almost explosive spread of the disease during the past 2 years. Practices must be adopted that will immediately reduce losses from black shank, that will reduce the amount of the fungus which can act as a source of spread, and that will gradually tend to eradicate the fungus from individual farms and eventually from neighborhoods.

Based on our present knowledge of the fungus and its habits, there is good reason to believe that a program of control can be successful for any farmer who is willing to take the time to become informed on the subject and then put what he has learned into practice.

It is common knowledge in areas in Kentucky where black shank is most prevalent and destructive that the first year the disease appears in a field the loss is negligible, but when the field is used a second or third season the loss may be almost total. This means that a rotation long enough to eradicate the fungus, with tobacco grown only once in the rotation, is certain to be successful in reducing losses to practically nothing the first year, as well as in successive years, if a fresh piece of ground is used; provided, of course, that the field does not receive drainage from an infested field used the previous year, and is prepared and worked with clean tools and machinery, and contaminated water is not used in watering the bed or in setting plants.

Growers in areas where the disease has not been reported or where it is present on only a few farms should watch for it. If plants are seen that appear to be drowning but which on examination are found to have a blackened shank extending from underground up the stalk, the diseased plant should be dug, put in a bag to prevent scattering dirt, and taken to the county agent or someone competent to determine the cause. If it is black shank the spot from which it came should be drenched with a solution of Nabam (see page 17). The same treatment should be given to every black shank plant that is found and such plants should be burned. In this way the fungus will be prevented from

multiplying and there will be no spread from that point because, so far as is known, the fungus multiplies only on or in the plant. Removal of plants will, of course, greatly reduce the carry-over to the next year and with spot sterilization may prevent such carry-over entirely.

Continuous tobacco

The minimum time necessary to free a field from the black shank fungus has not been determined for certain, but at present it appears probable that it may be as short a time as 1 year. Those who have but a single field satisfactory for tobacco *should not grow tobacco for a year* if the field is contaminated with the black shank fungus. There should be more specific information by that time on the persistence of the fungus and when it will be safe to plant the infested field again without danger of loss. If it is found that the fungus is almost completely eliminated in 1 year, it may be safe to grow tobacco the next year, provided a susceptible variety is grown, provided that the tools have all been cleaned to prevent recontamination, and provided that a very close watch is kept for the first signs of black shank and, at the first sign, the diseased plants are carefully removed and the spot sterilized with a solution of Nabam, which is sold commercially as Dithane D14 or Parzate Liquid Fungicide.[1] This will prevent multiplication of the fungus and spread from that point and, if the carry-over from the previous year is slight, may result in an extremely small loss. Instances are known where tobacco has been grown continuously on the same land by this method, or a variation of it, with the loss of only a few plants a year. This method of growing tobacco should be attempted only by persons with very limited tobacco land and by persons who are extremely careful.

It would seem, at first thought, that a resistant variety should be used in a field of this kind when it is first put back in tobacco, but this probably is not so. It has already been mentioned that the resistant varieties are sometimes killed by black shank and many plants are infected but not killed. The fungus can continue to multiply in

[1] This solution should contain 1 part of Nabam in 400 parts of water. It may be made up by adding 2 to 3 tablespoons (1 ounce) of Nabam to a 10-quart bucket of water. The soil should be loosened and the spot thoroughly soaked with the solution. In the directions "For County Committees on Tobacco Black Shank" and in the folder printed by the Burley Auction Warehouse Association formaldehyde was recommended. However, it does not penetrate the soil as deeply as the water in which it is dissolved. Studies by R. A. Chapman, of the Kentucky Agricultural Experiment Station, have shown that 1 part Nabam to 400 parts water prevents infection from infested soil and indicate that Nabam penetrates the soil more deeply than formaldehyde. Nabam has also prevented infection when the black shank fungus has been introduced into soil treated once three weeks previously.

these plants after harvest and so leave the soil contaminated. If susceptible plants are used and they become infected, the disease will develop rapidly, the plants will soon wilt, and at this stage they can be removed and the spot sterilized, thereby leaving the field relatively free from infection.

Program on a farm with only one field fit for tobacco

1951—Black shank in field.

1952—Grow no tobacco.

1953—If experiments indicate it is relatively safe, set a susceptible variety of tobacco, remove diseased plants, if they occur, and spot sterilize (see page 17).

1954—If 1953 crop was successful, continue with tobacco, but with constant watch for diseased plants, and spot sterilize when found.

Two-year rotation

The shortest rotation, other than continuous tobacco, is a 2-year rotation. For those growers with only enough good tobacco ground for a 2-year rotation, it should be possible to alternate between two fields, with a constant watch for diseased plants and removal of them on first evidence of disease, followed by spot sterilization with Nabam. Great care should be taken to prevent contamination of the clean field so that it could be put in tobacco a second year if experimental work should prove that one year is not long enough to get rid of the fungus in a contaminated field. In a 2-year rotation, resistant varieties should be safe to use, if good varieties resistant to black root rot as well as to black shank were available; but a careful grower probably will keep his fields freer from black shank by raising a susceptible variety and spot sterilizing.

Program on a farm with two fields suitable for tobacco

FIELD 1	FIELD 2
1951—Black shank in field.	1951—In grass; no history of black shank.
1952—Volunteer grain and vetch or other cover crop.	1952—Tobacco; if disease appears, remove plants and spot sterilize.
1953—Tobacco; remove diseased plants, if any, and spot sterilize (see page 17).	1953—Volunteer grain and vetch.
1954—Volunteer grain and vetch.	1954—Tobacco; handle as in 1952.
1955—Tobacco.	

Three-year rotation

Farmers with enough land for a longer rotation should plan on at least a 3-year rotation—that is, tobacco in a given field in 1952 and again in 1955. By that time there should be definite information on the length of time the fungus lasts in the soil, and practices can be governed accordingly.

Selection of a New Field for Tobacco

A farmer who has been growing tobacco continously in the same field and has had loss from black shank should select a field for his next crop that does not receive any drainage water from a black shank field or, if it does, the waterway across the field should be left in grass above the high-water mark. The new field should not be along a road if the field is lower than the road and receives drainage water from it, unless all of the road water can be carried across the field on a grassed waterway. If the field is about level with the road, a strip of grass about 20 feet wide should be left between the road ditch and the tobacco. This will tend to filter out the fungus that may be in the ditch water when it overflows the grass. The field should not receive drainage water from a barnyard or the yard around a tobacco barn, and it should be so located that no one has to go across a contaminated field to reach it.

Precautions Against Contamination of the New Field

The black shank fungus is carried in running water but also in clods of dirt on shoes, horses' hoofs, and in dirt clinging to all kinds of machinery. To prevent contamination of a new field it is necessary that all tools that have been used in a black shank field be cleaned of dirt as thoroughly as possible before preparing the new plant bed and the new field.

It is probably not necessary to sterilize each piece of machinery, but it is necessary to remove as completely as possible all masses of dirt that might drop off the machinery into the clean field. Machinery can be cleaned if water under pressure is available for washing. It can also be cleaned by using a putty knife as a scraper, or various kinds of wire brushes. If a creek or pond is handy, much of the dirt could be soaked off by standing the machinery in water for a time and then scrubbing it. Water from the pond should not be used for setting water the coming season.

It is so important that the machinery be clean that the farmer can afford to give careful thought to the best methods to be used under his conditions. It is better to do the cleaning on a grass plot rather than in a tobacco barn or in a barnyard where the tools may be contaminated again by the dirt left on the ground, and it is also better to do the cleaning as near the old infested field as possible, so as not to distribute dirt from the black shank field over the farm. It would be highly desirable for each farmer to make a practice of cleaning all of his machinery in the fall before storage for winter, so that this work need not be done when the weather is satisfactory for plowing and fixing the ground.

Selection of a Site for the Tobacco Bed

The new tobacco bed should be placed where it will receive no drainage from a black shank field and where dirt from the barnyard and tobacco barn is not likely to be carried to it on the feet of animals or men. It should be located where it can be reached without walking across a black shank field, and it should be in a position where the plants can be carried to the new field without going near the old black shank field. The bed should be prepared with clean tools, and if watering is necessary the water should be from a cistern, well, spring, a pond that does not receive drainiage from a black shank field, or a city water supply; not stream or river water.

Grow Your Own Tobacco Plants

Every grower, whether in a black shank area or not, should make a sufficiently large bed, and care for it carefully, so that it will not be necessary to get any plants from another farm. In black-shank-free areas in other states, when plants have been destroyed by blue mold, growers have gotten plants any place they could be found, without regard to disease, and some have carried black shank to their farms. In case of a plant bed failure in a black shank area in Kentucky, a grower would be much safer to go to a black-shank-free area for plants, but should take every precaution not to carry black shank to the farm from which he gets the plants.

Setting the Crop

At setting time every effort should be made to see that all tools used in setting be as clean as possible before commencing work, particularly if they are borrowed tools that have been used on a black shank farm. Those doing the setting should see that their shoes are free from clods of dirt before entering the field, and particularly if they are hired labor from a farm where black shank was present the year before. Black shank can be introduced in setting water if it is taken from an infested creek or river. Pond water, if the pond receives no drainage from a black shank field, cistern water, spring water, and water from town or city water supplies should be safe to use.

Care of the Crop

The tobacco grower should be on the alert all summer to see that no one enters the field who has been in a black shank field recently. Work animals' feet should be cleaned of dirt, cultivators that had previously been used in a black shank field should be cleaned, and all other precautions taken to prevent contamination.

A constant watch should be kept for the first appearance of black shank. If a single plant is found it should be dug out carefully, put in a paper bag, carried from the field and burned. Then the place from which the plant was removed should be thoroughly drenched with a solution of 1 part Nabam to 400 parts of water after loosening the soil (see page 17). This is a precaution that should be followed everywhere in the state, whether in black shank areas or in areas that have been free up to this time. Remember that the first black shank plants are likely to appear after a rainy period and that the

plants look as though they had been drowned. The fungus multiplies in the tissue of the plant, not in the soil so far as is known, and if the plant is removed early there will be little chance of multiplication, and little danger of spread from that point; whereas if the diseased plant is left the fungus may spread, during the next rainy period, to many neighboring plants or be carried longer distances by flowing water and show up in another part of the field.

Disposal of Tobacco Stalks and Barn Sweepings

Tobacco stalks and barn sweepings from a black shank crop should not be used as bedding or put on the manure pile. They may be burned or put on grassland that does not drain onto land that is to be used for tobacco or into a creek or river; or they may be put back, during a dry period, on the field from which they came if it has been sown to a permanent grass.

Tobacco Stems in Commercial Fertilizer

Tobacco stems are used in quantities in commercial fertilizers. Fertilizer containing tobacco stems is perfectly safe to use, so far as tobacco diseases are concerned, as the stems are sterilized before being delivered to the fertilizer mixing plant.

Visiting and Trading Labor and Tools

Black shank can be carried from one farm to another on shoes, automobile tires and fenders, on the floor of the car, and on all kinds of machinery. Visitors from black shank farms, when visiting clean farms, should first be sure their shoes are free from dirt and that clods of dirt are not on the floorboard ready to be kicked out when they get out of the car. As an added precaution, visitors should stay entirely away from the tobacco field.

In areas where labor and tools are traded, the greatest of care should be taken to see that all tools are clean before they leave a farm, and the farmer on whose farm the tools are to be used should assure himself that they *are* clean before he allows them to enter his farm.

Black Shank and Irrigation

Irrigation of tobacco is being tried in various parts of the state and particularly along rivers that do not dry up during a drouth. While it seems clear that water for plant beds and for setting should

not be taken from creeks or streams in infested areas, it is a question whether the same can be said with regard to water for irrigation. Certainly it is safer not to use such water for irrigation, but if it proves safe to use, growers should not be discouraged from using it.

In the spring, at plant bed time and during setting, creeks and rivers are much more likely to be contaminated with black shank by water draining from infested fields than during a protracted drouth, when irrigation would be most beneficial. It is very doubtful that the black shank fungus would remain for any appreciable time in creek or river water during a protracted drouth. Therefore, if a person were certain, during a drouth, that heavy rains had not fallen higher up the river, it might be safe to use the water for irrigation. If, however, a heavy rain had fallen in a limited area higher up the river, so that there was little rise in the river, the water might be contaminated without its being suspected, and black shank might result. It is possible that farmers living on streams or rivers can tell from the color or appearance of the water whether it is carrying dirt from eroded fields.

Several growers have taken water from creeks and rivers that are known to be contaminated at certain seasons of the year, and irrigated tobacco without black shank developing. There is danger that after irrigating two or three crops they may believe it is safe to use the water at any time and irrigate soon after setting, to help the newly set plants. At this season the water is likely to be contaminated and might easily result in total loss of the crop.

Black Shank and Land Values

There is no reason why black shank should reduce land values. Some farmers have tried to keep secret the fact that they have had black shank, with the idea that they might sell the farm and move to a black-shank-free farm. The chances are very good that they would carry the fungus with them on tools and machinery and gain nothing by the move. The better way is to recognize the trouble and proceed to get rid of it by rotation and sanitary measures.

Rotation and Farm Income

Since the introduction of root-rot-resistant varieties of burley tobacco many growers have turned to the practice of growing tobacco each year on the same piece of ground. The land has usually been heavily fertilized, manured, and tobacco stalks returned. This has

increased yields and usually has increased quality over what was grown on unfertilized land, but it has also increased greatly the chance of black shank becoming established and the chance of heavy loss from it.

If tobacco is grown in a rotation, in order to control black shank, yield and quality of the crop should not necessarily be reduced. Growers now know the value of high fertility for tobacco land, and many will undoubtedly fertilize the rotation plots ahead of tobacco so that the soil will be in better condition for tobacco. It has been demonstrated in the soil fertility plots at the Experiment Station that tobacco grown in a rotation of several years of grass is superior in quality to tobacco grown on a plot continuously. Another immediate effect of rotation will be to greatly improve the quality of hay, pasture, or any other crop that is grown on the heavily fertilized tobacco land. A rotation of tobacco and grass will mean that more of the farm is improved by fertilization than would likely be improved without such rotation, and income from pastures and other crops grown on the fertilized ground should more than make up for any possible reduction of income from tobacco.

Summary of Control Measures

The program of control and eradication of black shank discussed in this bulletin can be summarized as follows: If you are in a black shank area, grow tobacco each year on a clean piece of ground and see to it that the black shank fungus is not carried into this field from an infested field by running water, on tools, or on the feet of men or work animals, or in any other way.

Every farmer, whether in a black shank area or not, should be on the alert for the first signs of black shank in his patch. If he is not familiar with the disease he should have it diagnosed by someone who is. Care should be used in removing the plant from the field to see that no dirt is scattered. If the plant proves to have black shank, the spot from which it was removed should be drenched with 1 part of Nabam (see page 17) to 400 parts of water, and the field preferably sown to grass in the fall. Following a system of this kind the fungus should soon disappear from a farm.

Growers should understand that success in controlling the disease one year will not mean that danger is over. Plans should be made for several years ahead and followed carefully if losses in the future are to be prevented.

10M—12-51